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JP 060066129 A

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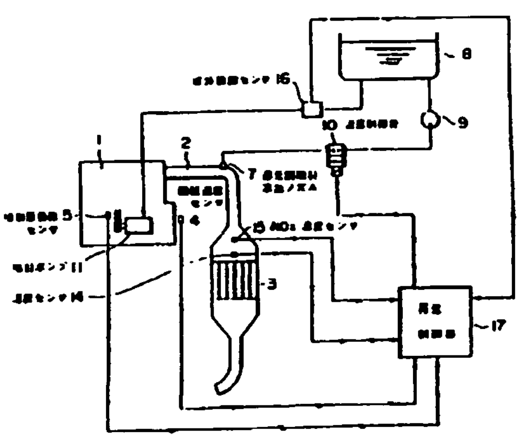
(54) Abstract Title

Apparatus and method for regenerating NOx catalyst for diesel engines

(57) An apparatus and a method for regenerating an NOx catalyst for a diesel engine which are capable of regenerating an NOx catalyst which as a lower performance due to accumulated SOx. The regeneration apparatus is provided with an NOx catalyst (3) placed in an exhaust pipe (2), a reductant fuel addition nozzle (7), a flow rate control valve (10) for controlling a feed rate of a reductant fuel supplied to the reductant fuel addition nozzle (7), a sensor (14) for detecting the inlet temperature of the NOx catalyst (3), and a regeneration controller (17) adapted to compute the quantity of SOx taken into the NOx catalyst (3) during a period of time in which the inlet temperature of the reductant fuel is not higher than a predetermined level with a zero feed rate instruction given to the flow rate control valve (10), an output, when the inlet temperature becomes higher than a predetermined level to start adding the reductant fuel, an instruction for supplying the reductant fuel the quantity of which is larger than a predetermined quantity thereof and suitable for the operational condition of a diesel engine (1) to the flow rate control valve (10).



4 ... rotational speed sensor
5 ... injection rate detecting sensor
7 ... reductant fuel addition nozzle
10 ... flow rate control valve
11 ... injection pump
14 ... temperature sensor
15 ... NOx concentration sensor
16 ... component detecting sensor
17 ... regeneration controller

GB 2 328 626 A

FIG. 1

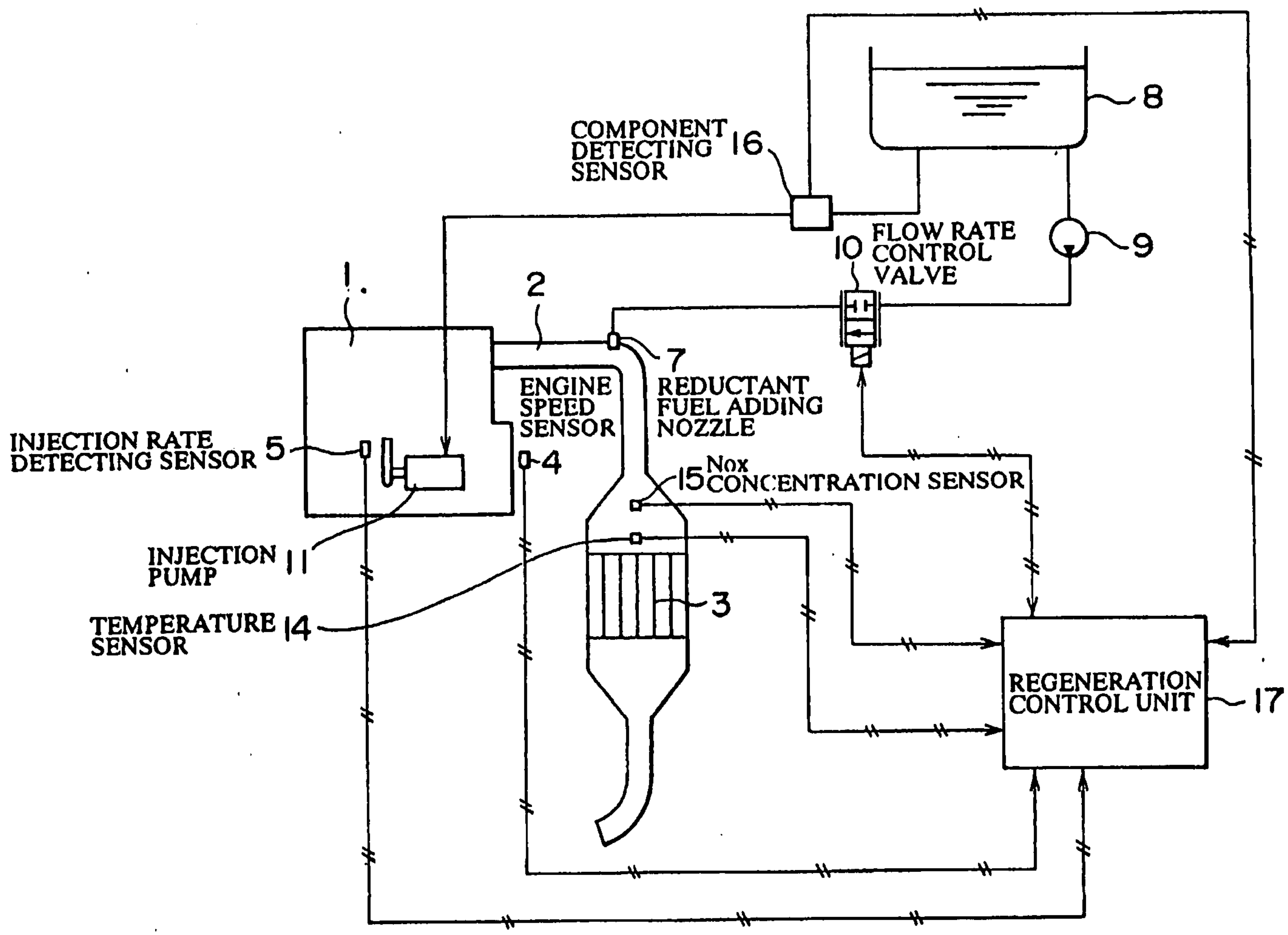

1
2
COMPONENT DETECTING SENSOR 16
8
9
10 FLOW RATE CONTROL VALVE
7 REDUCTANT FUEL ADDING NOZZLE
ENGINE SPEED SENSOR
4
INJECTION RATE DETECTING SENSOR 5
15 Nox CONCENTRATION SENSOR
INJECTION PUMP 11
3
TEMPERATURE SENSOR 14
REGENERATION CONTROL UNIT
17

FIG. 2

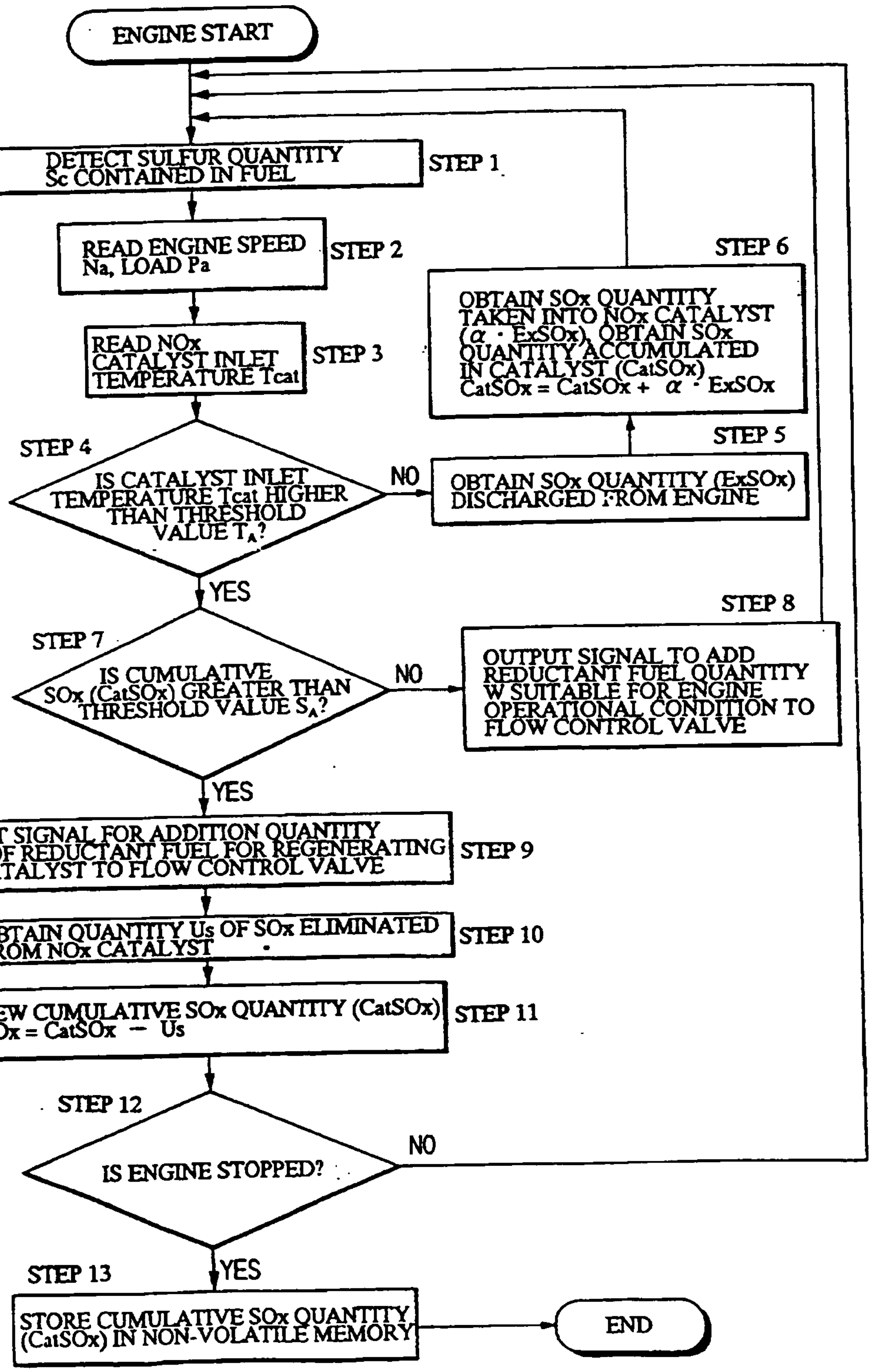

ENGINE START
DETECT SULFUR QUANTITY Sc CONTAINED IN FUEL
STEP 1
READ ENGINE SPEED Na, LOAD Pa
STEP 2
READ NOx CATALYST INLET TEMPERATURE Tcat
STEP 3
STEP 4
IS CATALYST INLET TEMPERATURE Tcat HIGHER THAN THRESHOLD VALUE T_A?
NO
OBTAIN SOx QUANTITY (ExSOx) DISCHARGED FROM ENGINE
STEP 5
OBTAIN SOx QUANTITY TAKEN INTO NOx CATALYST ($\alpha \cdot$ ExSOx), OBTAIN SOx QUANTITY ACCUMULATED IN CATALYST (CatSOx)
CatSOx = CatSOx + $\alpha \cdot$ ExSOx
STEP 6
YES
STEP 7
IS CUMULATIVE SOx (CatSOx) GREATER THAN THRESHOLD VALUE S_A?
NO
OUTPUT SIGNAL TO ADD REDUCTANT FUEL QUANTITY W SUITABLE FOR ENGINE OPERATIONAL CONDITION TO FLOW CONTROL VALVE
STEP 8
YES
OUTPUT SIGNAL FOR ADDITION QUANTITY W + R OF REDUCTANT FUEL FOR REGENERATING NOx CATALYST TO FLOW CONTROL VALVE
STEP 9
OBTAIN QUANTITY Us OF SOx ELIMINATED FROM NOx CATALYST
STEP 10
RENEW CUMULATIVE SOx QUANTITY (CatSOx)
CatSOx = CatSOx − Us
STEP 11
STEP 12
IS ENGINE STOPPED?
NO
YES
STEP 13
STORE CUMULATIVE SOx QUANTITY (CatSOx) IN NON-VOLATILE MEMORY
END

FIG.3

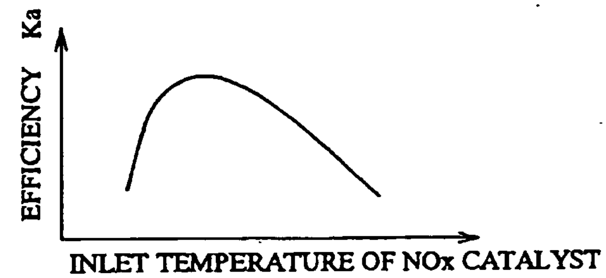


FIG.4

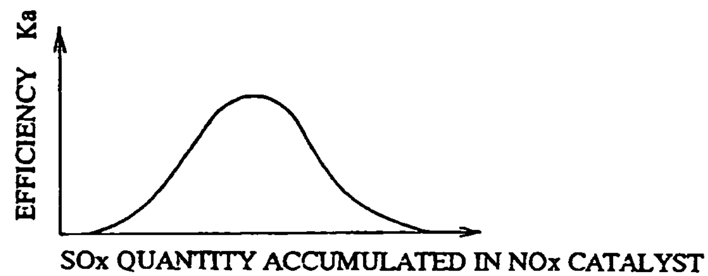


FIG.5

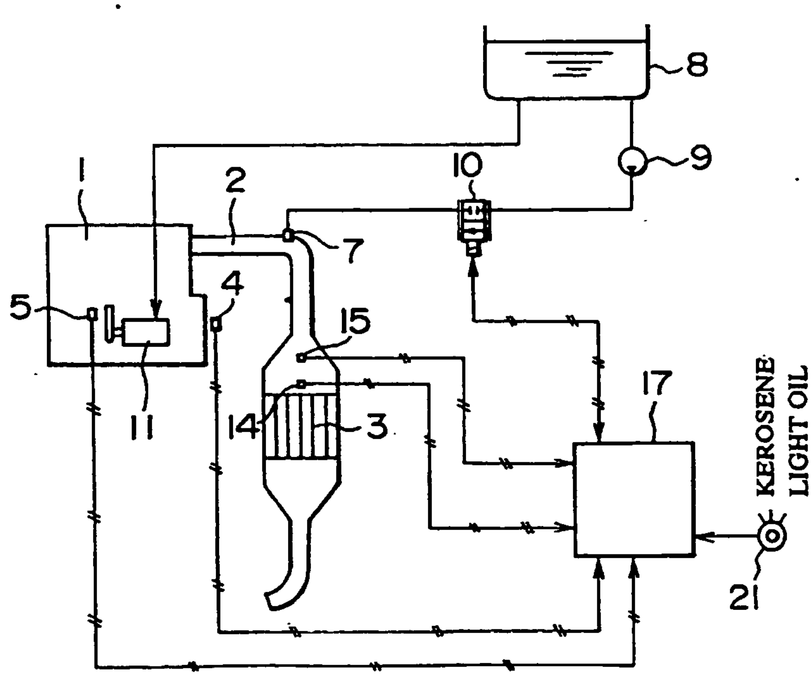


FIG.6

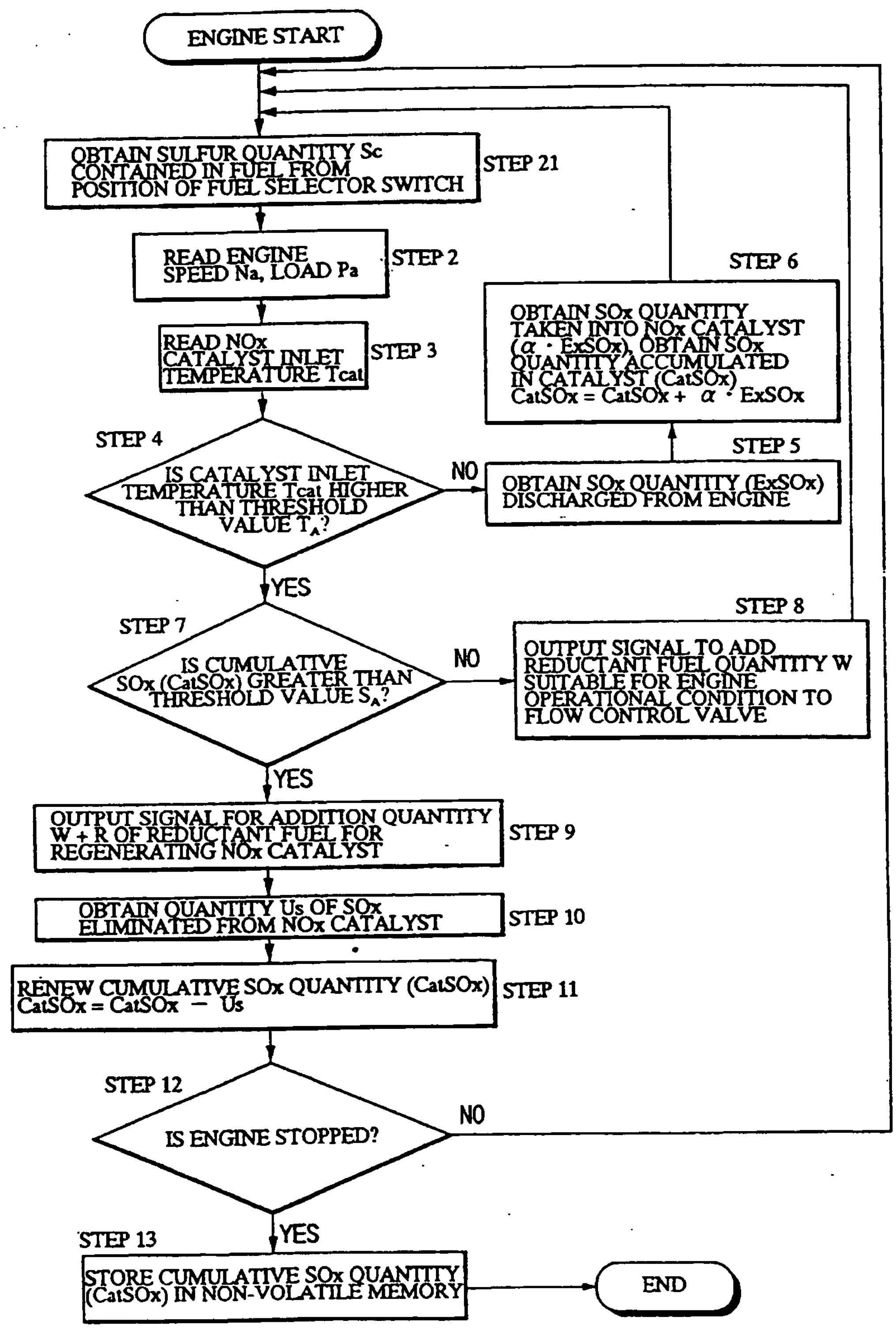

ENGINE START
OBTAIN SULFUR QUANTITY Sc CONTAINED IN FUEL FROM POSITION OF FUEL SELECTOR SWITCH
STEP 21
READ ENGINE SPEED Na, LOAD Pa
STEP 2
READ NOx CATALYST INLET TEMPERATURE Tcat
STEP 3
STEP 4
IS CATALYST INLET TEMPERATURE Tcat HIGHER THAN THRESHOLD VALUE T_A?
NO
OBTAIN SOx QUANTITY (ExSOx) DISCHARGED FROM ENGINE
STEP 5
STEP 6
OBTAIN SOx QUANTITY TAKEN INTO NOx CATALYST ($\alpha \cdot$ ExSOx), OBTAIN SOx QUANTITY ACCUMULATED IN CATALYST (CatSOx)
CatSOx = CatSOx + $\alpha \cdot$ ExSOx
YES
STEP 7
IS CUMULATIVE SOx (CatSOx) GREATER THAN THRESHOLD VALUE S_A?
NO
STEP 8
OUTPUT SIGNAL TO ADD REDUCTANT FUEL QUANTITY W SUITABLE FOR ENGINE OPERATIONAL CONDITION TO FLOW CONTROL VALVE
YES
OUTPUT SIGNAL FOR ADDITION QUANTITY W + R OF REDUCTANT FUEL FOR REGENERATING NOx CATALYST
STEP 9
OBTAIN QUANTITY Us OF SOx ELIMINATED FROM NOx CATALYST
STEP 10
RENEW CUMULATIVE SOx QUANTITY (CatSOx)
CatSOx = CatSOx − Us
STEP 11
STEP 12
IS ENGINE STOPPED?
NO
YES
STEP 13
STORE CUMULATIVE SOx QUANTITY (CatSOx) IN NON-VOLATILE MEMORY
END

FIG. 7

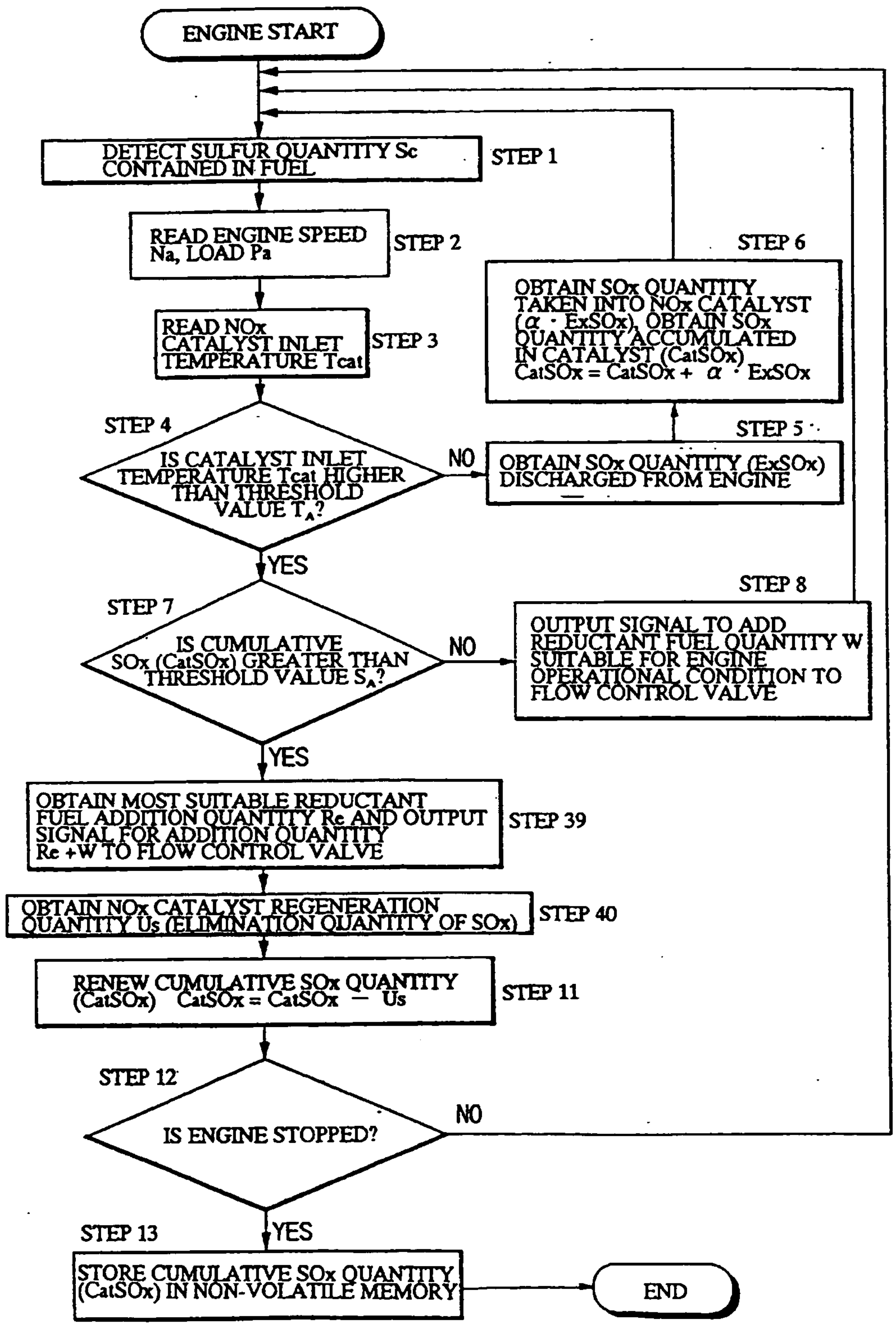

ENGINE START
DETECT SULFUR QUANTITY Sc CONTAINED IN FUEL
STEP 1
READ ENGINE SPEED Na, LOAD Pa
STEP 2
READ NOx CATALYST INLET TEMPERATURE Tcat
STEP 3
STEP 4
IS CATALYST INLET TEMPERATURE Tcat HIGHER THAN THRESHOLD VALUE T_A?
NO
STEP 5
OBTAIN SOx QUANTITY (ExSOx) DISCHARGED FROM ENGINE
STEP 6
OBTAIN SOx QUANTITY TAKEN INTO NOx CATALYST ($\alpha \cdot$ ExSOx), OBTAIN SOx QUANTITY ACCUMULATED IN CATALYST (CatSOx) CatSOx = CatSOx + $\alpha \cdot$ ExSOx
YES
STEP 7
IS CUMULATIVE SOx (CatSOx) GREATER THAN THRESHOLD VALUE S_A?
NO
STEP 8
OUTPUT SIGNAL TO ADD REDUCTANT FUEL QUANTITY W SUITABLE FOR ENGINE OPERATIONAL CONDITION TO FLOW CONTROL VALVE
YES
OBTAIN MOST SUITABLE REDUCTANT FUEL ADDITION QUANTITY Re AND OUTPUT SIGNAL FOR ADDITION QUANTITY Re +W TO FLOW CONTROL VALVE
STEP 39
OBTAIN NOx CATALYST REGENERATION QUANTITY Us (ELIMINATION QUANTITY OF SOx)
STEP 40
RENEW CUMULATIVE SOx QUANTITY (CatSOx) CatSOx = CatSOx − Us
STEP 11
STEP 12
IS ENGINE STOPPED?
NO
YES
STEP 13
STORE CUMULATIVE SOx QUANTITY (CatSOx) IN NON-VOLATILE MEMORY
END

FIG. 8

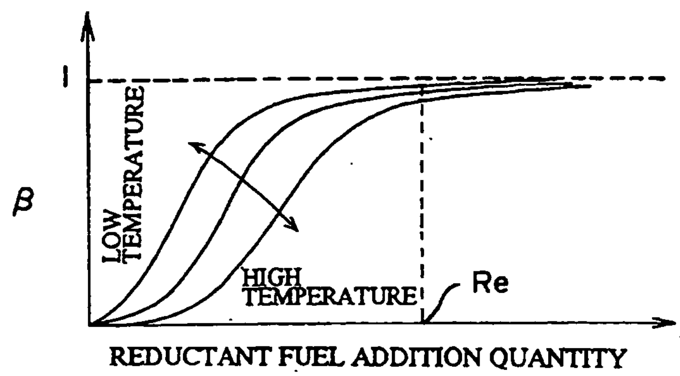

1
β
LOW TEMPERATURE
HIGH TEMPERATURE
Re
REDUCTANT FUEL ADDITION QUANTITY

FIG. 9

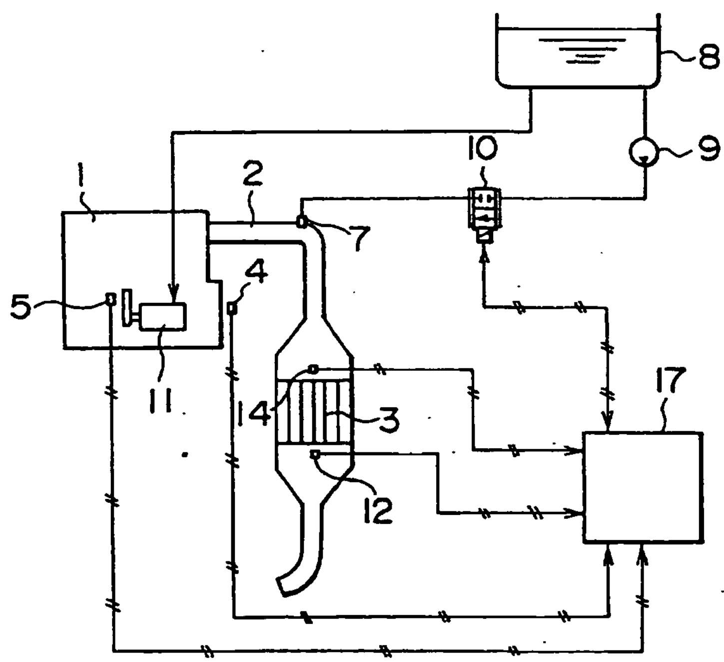

8
9
10
1
2
7
4
5
11
14
3
17
12

FIG. 10

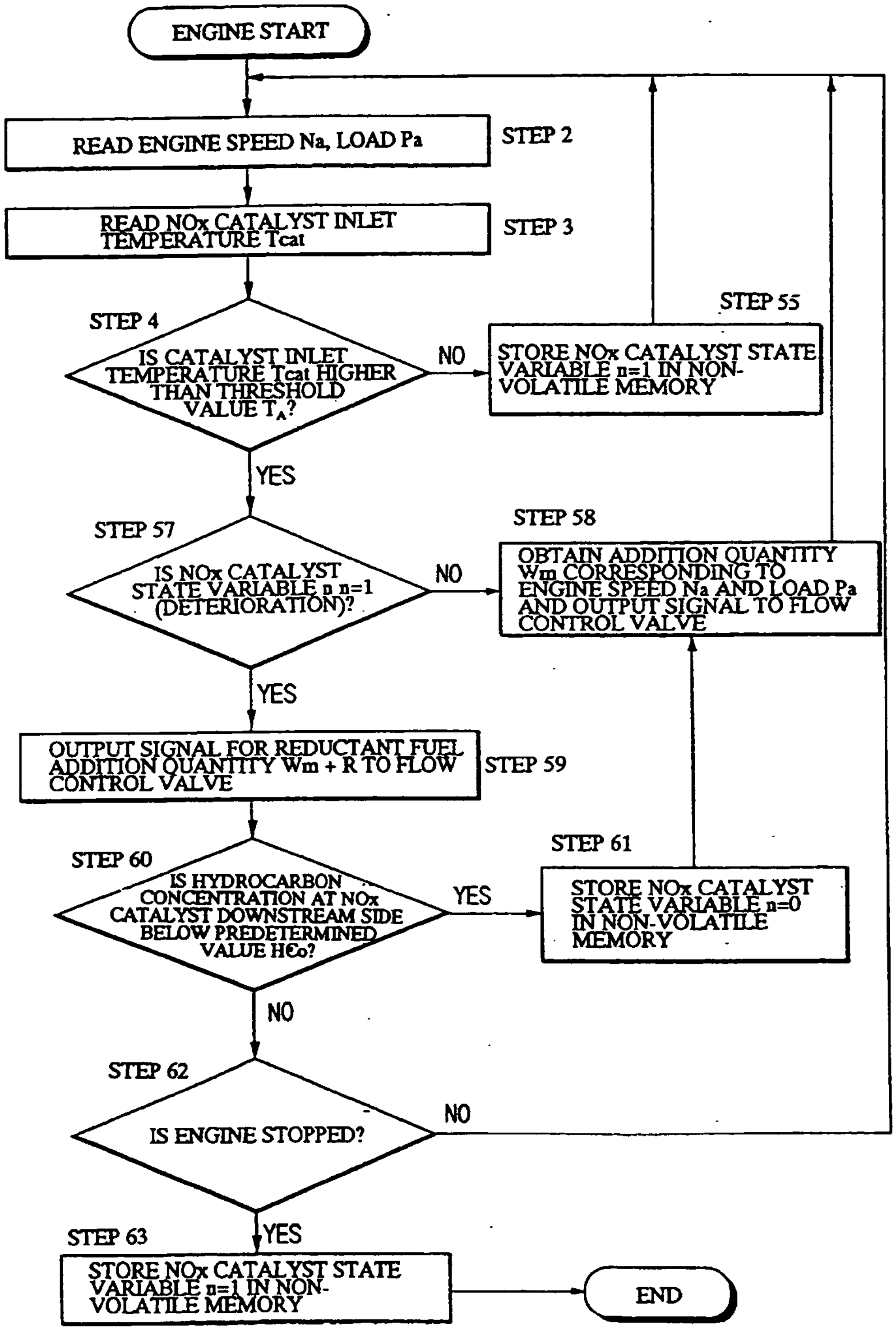

ENGINE START
READ ENGINE SPEED Na, LOAD Pa
STEP 2
READ NOx CATALYST INLET TEMPERATURE Tcat
STEP 3
STEP 4
IS CATALYST INLET TEMPERATURE Tcat HIGHER THAN THRESHOLD VALUE T_A?
NO
STEP 55
STORE NOx CATALYST STATE VARIABLE n=1 IN NON-VOLATILE MEMORY
YES
STEP 57
IS NOx CATALYST STATE VARIABLE n n=1 (DETERIORATION)?
NO
STEP 58
OBTAIN ADDITION QUANTITY Wm CORRESPONDING TO ENGINE SPEED Na AND LOAD Pa AND OUTPUT SIGNAL TO FLOW CONTROL VALVE
YES
OUTPUT SIGNAL FOR REDUCTANT FUEL ADDITION QUANTITY Wm + R TO FLOW CONTROL VALVE
STEP 59
STEP 60
IS HYDROCARBON CONCENTRATION AT NOx CATALYST DOWNSTREAM SIDE BELOW PREDETERMINED VALUE HCo?
YES
STEP 61
STORE NOx CATALYST STATE VARIABLE n=0 IN NON-VOLATILE MEMORY
NO
STEP 62
IS ENGINE STOPPED?
NO
YES
STEP 63
STORE NOx CATALYST STATE VARIABLE n=1 IN NON-VOLATILE MEMORY
END

FIG. 11

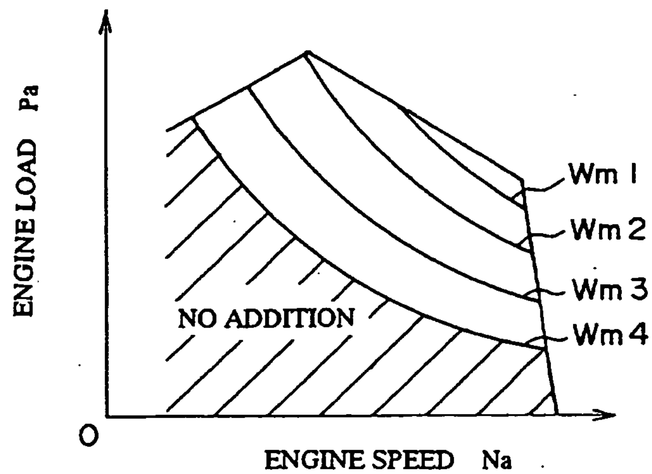

ENGINE LOAD Pa
NO ADDITION
Wm 1
Wm 2
Wm 3
Wm 4
0
ENGINE SPEED Na

FIG. 12

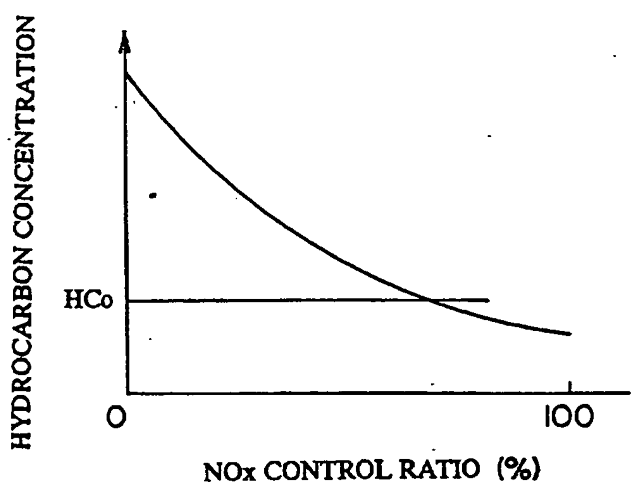
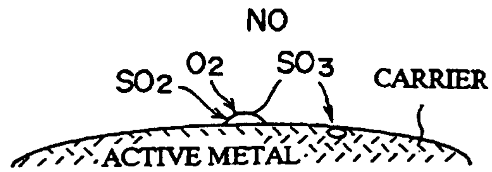
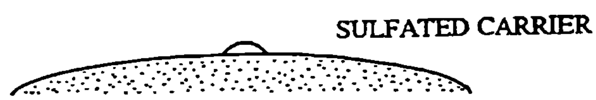

HYDROCARBON CONCENTRATION
HCo
0
100
NOx CONTROL RATIO (%)

FIG.13A



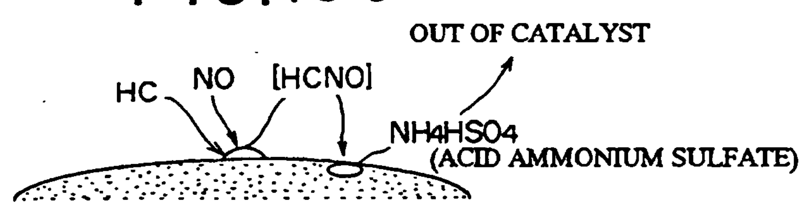
SOx DETERIORATION PROCESS

FIG.13B



SOx DETERIORATION STATE

FIG.13C



REACTIVATION PROCESS

FIG.13D

REACTIVATION STATE

APPARATUS AND METHOD FOR REGENERATING NOx CATALYST FOR DIESEL ENGINE

The present invention relates to an apparatus and a method for regenerating NOx catalyst for a diesel engine, and the invention particularly relates to an apparatus and a method for regenerating NOx catalyst for a diesel engine, which has lower performance.

Conventionally, Japanese Laid-open Patent No. 4-330314 has been known as a catalyst type of exhaust emission control device for a diesel engine, which reduces and decomposes NOx contained in the exhaust emissions from a diesel engine. According to Japanese Laid-open Patent No. 4-330314, the device is composed of a copper-zeolite NOx catalyst provided in an exhaust path of a diesel engine, a hydrocarbon sensor for detecting the hydrocarbon concentration in the exhaust emissions, and a fuel spraying means which is provided in the exhaust path at the upstream side of the hydrocarbon sensor and sprays fuel to the exhaust path to control the hydrocarbon concentration in the exhaust emissions within a predetermined range. According to the aforesaid configuration, based on a detected value of the hydrocarbon concentration, fuel is appropriately sprayed into the exhaust path from the fuel spraying means, and the hydrocarbon concentration in the exhaust emissions are kept within the predetermined range. The fuel sprayed from the fuel spraying means acts as a hydrocarbon reductant, and activates the copper-zeolite NOx catalyst in association with oxygen contained in the exhaust emissions from the diesel engine. Thus, it is proposed that the reduction of NOx in the exhaust emissions is promoted. However, the copper-zeolite NOx catalyst has lower performance in controlling NOx. Accordingly, in order to obtain higher performance in controlling NOx, large quantity of hydrocarbon for reduction is necessary, and this is disadvantageous in the running cost of the catalyst.

On the other hand, an NOx catalyst containing alkali-earth or rare-earth oxide and precious metal, and an NOx catalyst having silver as an active component show higher efficiency of controlling NOx with smaller quantity of reductant hydrocarbon as compared with a copper-zeolite catalyst.

However, the high-performance NOx catalyst containing alkali-earth or rare-earth oxide and precious metal, and the NOx catalyst having silver as an active component enable highly efficient control of NOx, but the only disadvantage is that they have lower durability against SOx, and therefore it is difficult to put them into practical use.

Mitigating the aforesaid disadvantages, the present invention is made, and its object is to provide an apparatus and a method for regenerating the NOx catalyst having a lower performance as a result that SOx is accumulated in the NOx catalyst due to sulphur in the fuel supplied to a diesel engine. The NOx catalyst applied to the present invention is not limited to the NOx catalyst containing alkali-earth or rare-earth oxide and precious metal, and the NOx catalyst having silver as an active component, as described above, but any NOx catalyst can be applied if it is an NOx catalyst which is generally deteriorated by SOx in exhaust emissions in a short time.

In order to attain the aforesaid object, a first aspect of an apparatus for regenerating an NOx catalyst for a diesel engine according to the present invention is in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst which is disposed in the exhaust pipe, and of which performance is easily lowered by absorbing SOx, characterised by including a reductant fuel adding nozzle for adding reductant fuel into the exhaust pipe, a flow rate control valve for controlling a feed rate of the reductant fuel to the reductant fuel adding nozzle, an NOx catalyst inlet temperature sensor disposed at an upstream side of the NOx catalyst, and a regeneration control unit for computing the quantity of SOx taken into the NOx catalyst during a period of time in which the inlet temperature of the NOx catalyst is not higher than a predetermined value from a signal from the NOx catalyst inlet temperature sensor and an instruction of a zero feed rate is given to the flow rate control valve, from the quantity of the diesel fuel supplied to a diesel engine during the period of time of zero feed rate, and outputting an instruction for supplying reductant fuel the

quantity of which is larg r than a pr determined quantity suitable for the operational condition of the diesel engine to the flow rate control valve when the inlet temperature exceeds a predetermined value and the reductant fuel is started to be added, and is characterised by the apparatus regenerating the NOx catalyst, which has lower performance due to SOx, by adding the reductant fuel the quantity of which is larger than the quantity suitable for the operational condition.

A second aspect of the invention based on the first aspect of the invention of the apparatus for regeneration is characterised by including either one of a selector switch for selecting the kind of diesel fuel, or a component sensor for detecting sulphur content in diesel fuel, and characterised by the regeneration control unit computing the quantity of SOx discharged from the diesel engine from a signal sent from either one of the selector switch or the component sensor and the feed rate of the diesel fuel to the diesel engine, and outputting to the flow rate control valve an instruction to supply the reductant fuel the quantity of which is larger than a predetermined quantity suitable for the operational condition of the diesel engine when the inlet temperature becomes a predetermined value or over and the reductant fuel is started to be added.

A third aspect of the invention of the apparatus for regeneration is in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst which is disposed in the exhaust pipe, and of which performance is easily lowered by absorbing SOx, characterised by including a reductant fuel adding nozzle for adding reductant fuel into the exhaust pipe at an upstream side of the NOx catalyst, a flow rate control valve for controlling a feed rate of the reductant fuel to the reductant fuel adding nozzle, an NOx catalyst inlet temperature sensor disposed at an upstream side of the NOx catalyst, a hydrocarbon concentration sensor disposed at a downstream side of the NOx catalyst, and a regeneration control unit, and is characterised by the regeneration control unit outputting an instruction for adding reductant fuel the quantity of which is larger than a predetermined quantity

suitable for the operational condition of the diesel engine to the flow rate control valve when the inlet temperature of the NOx catalyst is higher than a predetermined value from a signal from the NOx catalyst inlet temperature sensor and the hydrocarbon concentration at the downstream side of the NOx catalyst is greater than a predetermined value from a signal from the hydrocarbon concentration sensor to regenerate the NOx catalyst which has a lower performance due to SOx.

A first aspect of the invention of a method for regenerating an NOx catalyst for a diesel engine, is in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst which is disposed in the exhaust pipe, and of which performance is easily lowered by absorbing SOx characterised by including the steps of: on regenerating the NOx catalyst which has lower performance due to SOx, computing the quantity of SOx which is taken into the NOx catalyst during a period of time in which a diesel engine is operated and addition of reductant fuel is stopped due to the inlet temperature of the NOx catalyst being not higher than a predetermined value, and adding a predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for the operational condition, to regenerate the NOx catalyst deteriorated by SOx, when the operational condition of the diesel engine is changed with the inlet temperature being higher than the predetermined value and the reductant fuel is added.

A second aspect of the invention based on the first aspect of the invention of the method for regeneration has a characteristic that the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for the operational condition, is the quantity of reductant fuel suitable for the operational condition to which fixed quantity of reductant fuel is added irrespective of the operational condition of the engine.

A third aspect of the invention based on the first aspect of the invention of the method for regeneration has a characteristic that the predetermined quantity of reductant fuel, which is larger than the

quantity of reductant fuel suitable for the operational condition, is the quantity of reductant fuel suitable for the operational condition, which is incremented by a fixed ratio.

A fourth aspect of the invention based on the first aspect of the invention of the method for regeneration has a characteristic that the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for the operational condition, is variable quantity which is obtained by computing from the NOx concentration in the exhaust gas, the exhaust gas flow rate, and the exhaust gas temperature which are determined by the operational condition, and the quantity of SOx taken into the NOx catalyst.

A fifth aspect of the invention based on the first aspect of the invention of the method for regeneration has a characteristic that the quantity of SOx taken into the NOx catalyst is computed from a feed rate of the diesel fuel to the diesel engine.

A sixth aspect of the invention based on the first aspect of the invention of the method for regeneration has characteristics that when the operational condition of the diesel engine is changed with the inlet temperature being not higher than a predetermined value and addition of reductant fuel is stopped, before the regeneration of the NOx catalyst is completed, the cumulative quantity of SOx in the NOx catalyst at the time of stopping the addition is stored, and that the quantity of accumulated SOx in the NOx catalyst during a period of time in which addition of the reductant fuel is stopped is obtained by successively adding the quantity of SOx, which is taken into the NOx catalyst according to the operational condition of the diesel engine during the period of time of stopping, to the stored cumulative quantity of SOx.

A seventh aspect of the invention based on the first aspect of the invention of the method for regeneration has characteristics that when the diesel engine is stopped, before regeneration of the NOx catalyst is completed, cumulative quantity of SOx in the NOx catalyst at the time of stopping is stored, that after the diesel engine is stopped, the cumulative quantity of SOx is held, and that next time when the diesel engine is operated, the quantity of SOx, which is to be newly taken into

the NOx catalyst, is successively added to the stored cumulative quantity of SOx.

An eighth aspect of the invention based on the first aspect of the invention of the method for regeneration has a characteristic that the quantity of SOx, which is taken into the NOx catalyst, is obtained from the sulphur content in the diesel fuel supplied to the diesel engine.

A ninth aspect of the invention based on the first aspect of the invention of the method for regeneration has a characteristic that when regeneration of the NOx catalyst is completed, the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for the operational condition, is changed to the quantity suitable for the driving condition of the diesel engine at the time of completion of the regeneration.

A tenth aspect of the invention based on the ninth aspect of the invention of the method for regeneration has a characteristic that a point in time at which regeneration of the NOx catalyst is determined to be completed is the time when a calculated quantity of residual SOx during regeneration becomes equals to or less than a predetermined value, after successively computing the quantity of SOx which is eliminated from the NOx catalyst during regeneration and at the same time, computing the quantity of residual SOx during regeneration by subtracting the quantity of the eliminated SOx from the quantity of SOx remaining in the NOx catalyst.

An eleventh aspect of the invention based on the tenth aspect of the invention of the method for regeneration has a characteristic that the quantity of SOx which is eliminated from the NOx catalyst during the regeneration is obtained by computing from any one of the following: the NOx concentration in the exhaust gas, a flow rate of the exhaust gas, and the exhaust gas temperature which are determined by the operational condition of the diesel engine during regeneration, the quantity of SOx which is taken into the NOx catalyst, and the quantity of the added reductant fuel.

A twelfth aspect of the invention of a method for regeneration is in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst which is disposed in the exhaust pipe, and of which performance is easily lowered by absorbing SOx, characterised by including the step of: on regenerating the NOx catalyst which is deteriorated by SOx, adding the reductant fuel the quantity of which is larger than a predetermined quantity suitable for the operational condition of the diesel engine when the inlet temperature of the upstream side of the NOx catalyst is higher than a predetermined value and the hydrocarbon concentration of the downstream side of the NOx catalyst is greater than a predetermined value.

The principal of the action according to the aforesaid present invention will be explained by taking an NOx catalyst containing alkali-earth or rare-earth oxide and precious metal as an example. It is found that an NOx catalyst containing alkali-earth or rare-earth oxide and precious metal is abruptly deteriorated by SOx in exhaust emissions when reductant hydrocarbon is not added to the NOx catalyst, or when the temperature of the catalyst is lower than a predetermined temperature and does not act as NOx control reaction even if the reductant hydrocarbon is added thereto. Further, the catalyst, which is deteriorated by taking in SOx, releases the SOx taken in from the surface of the catalyst, and restores the performance. It is known that the restoring speed depends on the temperature of the exhaust emissions, the NOx concentration (quantity) in the exhaust emissions, the quantity of reductant hydrocarbon added to the exhaust emissions, and the quantity of SOx taken into the NOx catalyst. The present invention is made based on the above knowledge. For this purpose, first of all, the quantity of SOx in the exhaust emissions is obtained from the feed rate of the fuel supplied to the diesel engine when the temperature at the upstream side of the NOx catalyst and the load on the engine are less than predetermined values to compute the quantity of SOx taken into the NOx catalyst. The computing processing is continued during a period of time in which the engine is

being driven with the temperature of the upstream side of the catalyst being lower than a predetermined value to integrate the quantity of SOx taken into the NOx catalyst. Thereafter, when the operational condition of the engine is changed and the temperature of the inlet of the NOx catalyst becomes higher thana predetermined value, a predetermined quantity of the reductant fuel, which is larger than the quantity of the reductant fuel suitable for the operational condition, is supplied into the exhaust emissions, to regenerate the NOx catalyst in the exhaust pipe. If the quantity of the reductant fuel suitable for the operational condition of the engine is supplied, performance in controlling NOx is insufficient, and at the same time, the regeneration of the NOx catalyst deteriorated by SOx is carried out slowly. Accordingly, it is necessary to supply the reductant fuel the quantity of which is larger than the suitable quantity in order to restore the performance of the NOx catalyst in minimal time from the start of the reductant fuel supply.

As shown in Figure 13A to Figure 13D, when oxygen and sulphur dioxide in the exhaust emissions enter the NOx catalyst, the carrier of the active metal in the NOx catalyst becomes sulphated carrier, and is deteriorated by SOx. It is assumed that the carrier deteriorated by SOx generates acid ammonium sulphate when hydrocarbon and nitric oxide enter, and acid ammonium sulphate volatilises from the pores of the carrier, thereby the carrier is returned into a reactivated state. The speed at which the acid ammonium sulphate generates depends on the NOx concentration, hydrocarbon concentration in the emissions and the temperature thereof, and further the speed at which acid ammonium sulphate volatilises depends on the temperature of the emissions. Accordingly, it is found that the time taken to regenerate the NOx catalyst by supplying the reductant fuel the quantity of which is larger than the quantity suitable for the operational condition is determined based on the operational condition of the diesel engine and the emission temperature at the inlet of the NOx catalyst.

The SOx deterioration and regeneration mechanism of the aforesaid NOx catalyst takes place in the NOx catalyst containing alkali-earth or rare-earth oxide and precious metal, but it can be considered that the

other NOx catalysts such as Ag / alumina which hav abruptly lowered performance can be also regenerated from SOx deterioration by the same regeneration mechanism as described above.

Embodiments of the invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 is an explanatory diagram of a configuration of an apparatus for regenerating an NOx catalyst for a diesel engine according to a first embodiment of the present invention;

Figure 2 is a flowchart of a method for regenerating the NOx catalyst according to the first embodiment of the present invention;

Figure 3 is a graph showing the relationship between the temperature of the NOx catalyst and the SOx elimination efficiency in the NOx catalyst according to the first embodiment of the present invention;

Figure 4 is a graph showing the relationship between the cumulative quantity of SOx in the NOx catalyst and the SOx elimination efficiency in the NOx catalyst according to the first embodiment of the present invention;

Figure 5 is an explanatory diagram of a configuration of an apparatus for regenerating an NOx catalyst for a diesel engine according to a second embodiment of the present invention;

Figure 6 is a flowchart of a method for regenerating the NOx catalyst according to the second embodiment of the present invention;

Figure 7 is a flowchart of a method for regenerating an NOx catalyst according to a third embodiment of the present invention;

Figure 8 is a graph showing the relationship between the addition quantity of reductant fuel and the SOx elimination efficiency in the NOx catalyst according to the third embodiment of the present invention;

Figure 9 is an explanatory diagram of a configuration of an apparatus for regenerating an NOx catalyst for a diesel engine according to a fourth embodiment of the present invention;

Figure 10 is a flowchart of a method for regenerating the NOx catalyst according to the fourth embodiment of the present invention;

Figure 11 is a map of the addition quantity of reductant fuel according to the fourth embodiment of the present invention;

Figure 12 is a graph showing the relationship among an NOx controlling ratio, hydrocarbon concentration, and a predetermined value of the hydrocarbon concentration according to the fourth embodiment of the present invention;

Figure 13A to Figure 13D are explanatory diagrams for explaining steps in a mechanism from SOx deterioration to reactivation of the NOx catalyst according to the present invention, and Figure 13A is an explanatory diagram of a SOx deterioration process which is a first step;

Figure 13B is an explanatory diagram of a SOx deterioration state which is a second step;

Figure 13C is an explanatory diagram of a reactivation process which is a third step; and

Figure 13D is an explanatory diagram of a reactivation state which is a fourth step.

Referring now to the Figures, Figure 1 is an apparatus for regenerating an NOx catalyst 3 according to a first embodiment of the present invention, and the NOx catalyst 3 for controlling NOx in emissions is placed in an exhaust pipe 2 from a diesel engine 1 (hereinafter, referred to as an engine 1). The NOx catalyst 3 contains alkali-earth or rare-earth oxide and precious metal, and is composed of NOx catalyst which easily absorbs SOx (for example, NOx catalyst containing barium oxide and palladium), or NOx catalyst composed by having silver as an activated component, which is carried by alumina.

An engine speed sensor 4 for detecting engine speed is disposed at the engine 1. An injection rate detecting sensor 5 for measuring injection rate of diesel fuel (specifically, feed rate of diesel fuel to the engine 1) is disposed at a lever (not illustrated) of the engine 1, which interlocks with an accelerator pedal (not illustrated). A reductant fuel adding nozzle 7 for adding reductant fuel (reducing hydrocarbon) to emissions is disposed at a portion between the engine 1 and NOx catalyst 3. Fuel fed from a fuel tank 8 through a pump 9 is supplied into the reductant fuel adding nozzle 7 with the flow rate thereof being controlled by a flow rate control valve 10. The flow rate control valve 10 is controlled in response to an instruction from a controller described below

according to the driving conditions of the engin 1, and supplies necessary and sufficient amount of reductant fuel to the reductant fuel adding nozzle 7. Fuel for driving the engine 1 is supplied into an injection nozzle (not illustrated) from the fuel tank 8 by an injection pump 11, and is injected into a cylinder of the engine 1.

A sensor 14 for detecting the inlet temperature of the NOx catalyst 3 (hereinafter referred to as a temperature sensor 14) and an NOx concentration sensor 15 are disposed in the exhaust pipe 2 at the upstream side of the NOx catalyst 3. A component detecting sensor 16 for detecting the component of sulphur content in the fuel for driving the engine 1 is disposed at a portion between the fuel tank 8 and the injection pump 11. It should be noted that the place for setting the component detecting sensor 16 may be in a path for the reductant fuel, or in the fuel tank 8. Each of the sensors 4, 5, 14, 15, and 16 are connected to a regeneration control unit 17. The regeneration control unit 17 comprises a controller, and outputs an instruction for regenerating of the NOx catalyst 3 on receiving signals from the engine speed sensor 4, the injection rate detecting sensor 5, the temperature sensor 14, the NOx concentration sensor 15, and the component detecting sensor 16. In this embodiment, the temperature of the NOx catalyst 3 is measured by means of the temperature sensor 14 attached at the upstream side of the NOx catalyst 3, but it goes without saying that it is suitable to attach the temperature sensor 14 at the downstream side of the NOx catalyst 3 to measure the temperature.

A method for regenerating the NOx catalyst 3 with the aforesaid configuration will be explained with reference to a flowchart shown in Figure 2.

In step 1, an amount of sulphur Sc contained in the fuel for operating the engine 1 is detected by means of the component detecting sensor 16. In step 2, the operational condition such as rotational speed Na of the engine 1, and load Pa acting on the engine 1 is obtained by means of the regeneration control unit 17 based on the signals from the engine speed sensor 4 and the injection rate detecting sensor 5. In step 3, the inlet temperature Tcat of the NOx catalyst 3 is read by means of the temperature sensor 14.

In st p 4, it is determined whether the inlet temperature Tcat of the NOx catalyst 3 is higher than a threshold value TA, or not. For example, in a truck, a generator, or the like, when exhaust temperature is lower with lower load, the NOx catalyst 3 doesn't work, therefore it is necessary to stop adding reductant. Under the condition in which addition of the reductant is stopped, the NOx catalyst 3 suffers SOx deterioration.

In step 4, when the inlet temperature Tcat of the NOx is lower than the threshold value TA, a command is given to proceed to step 5. In step 5, the quantity of SOx (ExSOx), which is discharged from the engine 1, is obtained by a computation. The quantity of SOx is determined by the kind of fuel used and the quantity of the fuel burnt in the engine 1, and in this embodiment, this is obtained from the feed rate of the fuel into the cylinder of the engine 1 based on the operational condition of the engine 1 which is read in step 2, specifically, the engine speed Na and the load Pa.

In step 6, the quantity of SOx taken into the NOx catalyst ($\alpha \cdot$ ExSOx) is obtained from the quantity of discharged SOx (ExSOx), and the cumulative quantity of SOx (CatSOx) is obtained. In this embodiment, the cumulative quantity of SOx taken into the NOx catalyst 3 (CatSOx) is computed by [$\mathrm{CatSOx} = \mathrm{CatSOx} + \alpha \cdot \mathrm{ExSOx}$]. After step 6 is finished, a command is given to return to step 1, but normally, fuel is not frequently changed, therefore it may be suitable to return to step 2.

In step 4, when the inlet temperature Tcat is higher than the threshold value TA, a command is given to proceed to step 7. In step 7, it is determined whether the cumulative quantity of SOx (CatSOx) is greater than a threshold value SA or not. In step 7, when the cumulative quantity of SOx (CatSOx) is smaller than the threshold value SA, a command is given to proceed to step 8. In step 8, the regeneration control unit 17 is controlled in response to the operational condition of the engine 1, and outputs an instruction to the flow rate control valve 10 so that quantity of addition W of reductant fuel, which is suitable for controlling NOx discharged from the engine 1, is added.

In the present embodiment, the flow of the exhaust emissions is obtained from the data read in step 2 as the operational condition of the engine 1, specifically, from the engine speed Na and the load Pa of the engine 1. Further, in the present embodiment, necessary quantity of reductant fuel to be added is obtained from the performance of the NOx catalyst 3, and from the quantity of NOx discharged which is obtained by multiplying the flow by the NOx concentration value in the exhaust emissions, which is obtained from the NOx concentration sensor 15. However, when used for a truck or the like, an NOx concentration sensor which can be used on board has not been developed, therefore map data may be previously prepared, and the quantity of the reductant fuel to be added may be obtained from the engine speed Na and the load Pa.

After completing step 8, a command is given to return to step 1, but as in step 6, it is suitable to return to step 2. When the cumulative quantity of SOx (CatSOx) is greater than the threshold value SA in step 7, a command is given to go to step 9.

In step 9, an instruction is issued to the flow rate control valve 10 to add into the exhaust pipe 2 the reductant fuel that is the addition quantity W calculated and instructed in step 8, which is further incremented by a predetermined quantity R, specifically the addition quantity (W + R). The first object of the above is to attain necessary NOx control performance, which can be attained only by adding the addition quantity W + R greater than the addition quantity W suitable for the operational condition of the engine 1. The second object is to increase the regeneration speed of the NOx catalyst 3 deteriorated by SOx. In the present embodiment, the increase quantity R is always fixed irrespective of the operational condition of the engine 1, but control may be carried out by incrementing the addition quantity W determined by the operational condition of the engine 1 by a fixed ratio r. In this situation, the same operation as executed in step 8 is also carried out in step 9.

After completing step 9, a command is given to proceed to step 10, and based on the operational condition of the engine 1, the NOx catalyst inlet temperature Tcat, the cumulative quantity of SOx (CatSOx), and the reductant fuel addition quantity R, SOx quantity Us eliminated from the NOx catalyst 3 under this condition is obtained.

In the present mbodiment, the NOx concentration in exhaust emissions, which is obtained from the NOx concentration sensor 15, is measured. Efficiency Ka with which SOx in the NOx catalyst 3 is eliminated depends on the concentration of a nitrogen-containing hydrocarbon compound generating on the surface of the catalyst, specifically, on the NOx concentration in exhaust emissions, the quantity of reductant fuel added, and the temperature of exhaust gas. Regarding the temperature, the elimination efficiency Ka has the most suitable temperature as shown in Figure 3. In Figure 3, the axis of abscissa shows the temperature, and the axis of ordinates shows the efficiency Ka with which SOx in the NOx catalyst 3 is eliminated. When the integrated quantity of SOx (CatSOx) is greater, the elimination efficiency Ka is smaller as shown in Figure 4. In Figure 4, the axis of abscissa shows the quantity of SOx accumulated in the NOx catalyst 3, and the axis of ordinates shows the efficiency Ka with which SOx in the NOx catalyst 3 is eliminated. Including all of these conditions, the generation control unit 17 obtains the quantity of SOx Us eliminated from the NOx catalyst 3, specifically, the regeneration quantity Us of the NOx catalyst 3 from the SOx deterioration.

In step 11, according to the SOx quantity Us eliminated from the NOx catalyst 3, the numeral data of the cumulative quantity of SOx (CatSOx) in the NOx catalyst 3 is renewed according to the equation [CatSOx = CatSOx - Us]. After finishing step 11, a command is given to proceed to step 12, and it is determined whether the engine 1 is operated or not. When it is determined that the engine 1 is continuously operated, a command is given to return to step 1, but it is also suitable to return to step 2 as in step 6.

By repeating the aforesaid series of cycle, the quantity of SOx (CatSOx) accumulated in the NOx catalyst 3 is reduced, and after a while, it is determined that the regeneration of the NOx catalyst 3 is finished in the determining operation in step 7.

When it is determined that the engine 1 is stopped in step 12, the control is ended. At the time when the engine 1 is stopped, the NOx catalyst 3 normally maintains the deterioration state by SOx. For this

reason, in the present embodiment, the data of the SOx quantity (CatSOx) accumulated in the NOx catalyst 3 at this time is stored in non-volatile memory which can be held even in a situation in which the engine 1 is stopped. When the engine 1 is operated next time, the degree of the deterioration of the NOx catalyst 3 by SOx is to computed by using the stored data.

Figure 5 is an explanatory diagram of the configuration of an apparatus for regenerating the NOx catalyst 3 of the diesel engine 1 according to a second embodiment of the present invention. The same components as in the first embodiment are given the identical numerals and symbols, and the explanation thereof will be omitted. In the first embodiment, the component detecting sensor 16 is used for detecting the component of the fuel used for operating the engine 1, but in the second embodiment, a selector switch 21 for selecting the kind of diesel fuel is provided, and the selector switch 21 is connected to the regeneration control unit 17. For example the positions for selecting kerosene, light oil, and the like are provided at the selector switch 21, and the positions are switched by an operator according to the kinds of the diesel fuel to be used.

With reference to the flow shown in Figure 6, a control method in the second embodiment will be explained. The same steps as in the first embodiment are given the same step numbers, and the explanation thereof will be omitted. In step 21, based on the position of the selector switch 21, which is set by an operator, the controller in the regeneration control unit 17 determines the quantity of sulphur Sc contained in the diesel fuel selected. Next, a command is given to go to step 2, but the operations in step 2 and thereafter are the same as in the first embodiment, therefore the explanation will be omitted.

Next, with reference to the flow shown in Figure 7, a method for controlling the NOx catalyst 3 in the diesel engine 1 according to a third embodiment will be explained. The mechanical feature in the third embodiment is the same as in the first or second embodiment, therefore the explanation will be omitted. The same steps as in the first embodiment are given the same step numbers, and the explanation thereof will be

omitted. The operations in steps 1 to 7, in step 8, and in st p 11 and thereafter are the same as in the first embodiment. In the third embodiment steps 9 and 10 are different from those in the first embodiment.

In step 7, when the cumulative SOx quantity (CatSOx) in the NOx catalyst 3 is greater than the threshold value SA, a command is given to go to step 39. In step 39, in order to eliminate the accumulated SOx (CatSOx) in the NOx catalyst 3, the reductant fuel addition quantity Re, which is the most efficient at the time, specifically, the most suitable, is computed.

The addition quantity Re will be explained. The elimination efficiency Ka of SOx in the NOx catalyst 3 is increased following an increase in the addition quantity of the reductant fuel, but it tops out after a while. In Figure 8, the addition quantity of the reductant fuel for eliminating the accumulated SOx is shown by the axis of abscissa, and a ratio β of the elimination efficiency Ka to the maximum efficiency Kmax with which SOx in the NOx catalyst 3 is eliminated is shown by the axis of ordinates. As known from Figure 8, the addition quantity with which the efficiency begins to top out becomes smaller as the temperature of the exhaust gas becomes lower. Further, as described in the explanation of the regeneration method in the first embodiment, the ratio β varies depending on the operational condition of the engine 1, the inlet temperature Tcat of the NOx catalyst 3, and the integrated SOx quantity (CatSOx). The regeneration control unit 17 determines the most suitable addition quantity Re of the reductant fuel which can most efficiently eliminate the accumulated SOx from the NOx catalyst 3 at the time in consideration of the quantity of consumption of the reductant fuel, specifically, the fuel consumption of the engine 1. The regeneration control unit 17 adds the addition quantity W suitable for the operational condition of the engine 1 to this most suitable addition quantity Re, and outputs an instruction to the flow rate control valve 10 to add the reductant fuel addition quantity Re + W into the exhaust pipe 2.

After finishing step 39, a command is given to proceed to step 40, and the regeneration quantity Us of the NOx catalyst 3 from SOx by the addition quantity Re is obtained, and a command is given to proceed to step 11 in the first embodiment, and the operations thereafter are carried out. The explanation thereof will be omitted.

Next, the regeneration of the NOx catalyst 3 according to a fourth embodiment of the present invention will be explained. In the fourth embodiment, as shown in Figure 9, the component detecting sensor 16 and the NOx concentration sensor 15 are omitted, and a hydrocarbon concentration sensor 12 is disposed in the exhaust pipe 2 at the downstream side of the NOx catalyst 3, as compared with Figure 1 in the first embodiment. With the hydrocarbon concentration sensor 12, hydrocarbon concentration HC in the exhaust gas emitted from the NOx catalyst 3 is detected.

Regarding a method for regenerating the NOx catalyst 3 with the above configuration will be explained with reference to the flowchart shown in Figure 10. As compared to the first embodiment, step 2 to step 4 are the same, but step 1 is omitted, with step 4 and the steps thereafter being changed.

When the inlet temperature Tcat is not higher than the threshold value TA instep 4, a command is given to go to step 55. In step 55, the regeneration control unit 17 stores a state variable n = 1 of the NOx catalyst 3 in non-volatile memory (not illustrated), and then a command is given to return to step 2. The state variable n is a variable showing the state of the NOx catalyst 3 caused by the accumulation of SOx, and "n = 0" is set as a not-yet-deteriorated state of the NOx catalyst 3, while "n = 1" is set as a deteriorated state of the NOx catalyst 3. It should be noted that when "the inlet temperature Tcat is lower" in step 4, the NOx catalyst 3 is not necessarily in a deteriorated state, specifically, before the determination of the state. However, even if the inlet temperature Tcat is low, it is possible that the NOx catalyst 3 is deteriorated by the accumulation of SOx therein, therefore the situation in which "the inlet temperature Tcat is lower" in step 4 is set as a deteriorated state.

When the inlet temperature Tcat is higher than the threshold value TC in step 4, a command is given to go to step 57, and it is checked whether the state variable n of the NOx catalyst 3, which is stored in the non-volatile memory, is "1" (a deteriorate state), or "0" (a not-yet-deteriorated state). When $n = 0$, a command is given to go to step 58, and when $n = 1$, a command is given to go to step 59.

In step 58, the regeneration control unit 17 obtains the addition quantity Wm of the reductant fuel corresponding to the data of the engine speed Na and the engine load Pa (for example, torque) which are read in step 2 from an addition quantity map (see Figure 11) preciously stored, and issues an instruction to the flow control valve 10 to add the addition quantity Wm into the exhaust pipe 2. The addition quantity Wm is the quantity suitable for controlling NOx discharged from the engine 1 with the engine speed Na and the load Pa which are read. In Figure 11, as a level of addition quantity Wm, addition quantity level lines Wm1 to Wm4 (the addition quantity: Wm1 > Wm4) are only shown in the drawing, but the higher load side of the addition quantity level line Wm1 and each portion between the addition quantity level lines Wm1 to Wm4 are further divided into smaller meshes. Addition quantities Wm11, Wml2, ·· are inputted at the respective meshes. In an area where the engine speed Na or the load Pa is small, the inlet temperature Tcat is low, and the NOx catalyst 3 does not effectively operate, therefore in the present embodiment, the reductant fuel is not added. After step 58 is finished, a command is given to return to step 2.

In step 59, the regeneration control unit 17 gives the flow rate control valve 10 to add into the exhaust pipe 2 the reductant fuel which is the addition quantity Wm, calculated and instructed in step 58, further incremented by predetermined quantity R, specifically, the addition quantity (Wm + R). The objects of predetermined addition quantity R, and of adding the incremented quantity (Wm + R) are the same as in the first embodiment. Instead of being incremented by the predetermined quantity R, the addition quantity Wm may be incremented by the fixed ratio r as in the first embodiment.

In step 60, the regeneration control unit 17 determines whether the hydrocarbon concentration HC at the downstream side of the NOx catalyst 3, which is detected by the hydrocarbon concentration sensor 12, is less than a predetermined value HCo or not, and if it is less than the predetermined value HCo, a command is given to go to step 61. If it is less than the predetermined value HCo, as shown in Figure 12, NOx control rate is higher, specifically, NOx catalyst 3 is in a good condition. Accordingly, in step 61, the state variable n = 0 of the NOx catalyst 3 is stored in non-volatile memory, and a command is given to return to step 2.

If the hydrocarbon concentration HC is greater than the predetermined value HCo, a command is given to go to step 62,and it is determined whether the engine 1 is operated or not. When it is determined that the engine 1 is continuously operated, a command is given to return to step 2. On the other hand, when be engine 1 is stopped, a command is given to go to step 63, and the state variable n = 1 of the NOx catalyst 3, specifically, the deterioration state, is stored in the non-volatile memory, and the processing is ended. By repeating the above cycle of the present embodiment, the quantity of SOx (CatSOx) of the NOx catalyst 3 is also reduced, and the NOx catalyst 3 is regenerated.

In step 58 in the fourth embodiment, the reductant fuel addition quantity Wm is obtained from the addition quantity map in Figure 11, but it is suitable to provide the NOx concentration sensor 15 as shown in Figure 1 and obtain the addition quantity W as in step 8 of the first embodiment.

According to the present invention described above, with respect to the NOx catalyst 3 which is abruptly deteriorated by SOx, the feed rate of the fuel to the engine 1 is obtained when the inlet temperature Tcat of the NOx catalyst 3 is not higher than the predetermined value TA. The quantity of SOx which is taken into the NOx catalyst 3 during a period of time in which the inlet temperature Tcat is not higher than the predetermined value TA is calculated, and when the inlet temperature Tcat is higher than the predetermined value TA as a result that the operational condition of the engine 1 is changed and the reductant fuel is started to be supplied, a predetermined quantity of reductant fuel which is more than

the quantity of reductant fu l suitable for the operational condition is supplied into the exhaust emissions to regenerate the NOx catalyst 3 in the exhaust pipe 2. Thus, sufficient NOx control performance is obtained even from the NOx catalyst 3 deteriorated by SOx, and the NOx catalyst 3 can be recovered from the deterioration by SOx in a short time.

The present invention is useful as an apparatus and a method for regenerating an NOx catalyst for a diesel engine, which can regenerate a catalyst having lower performance as a result that SOx is accumulated in the NOx catalyst due to sulphur existing in the fuel which is supplied to the diesel engine.

CLAIMS:

1. An apparatus for regenerating an NOx catalyst for a diesel engine, in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe (2) predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst (3) which is disposed in said exhaust pipe (2), and of which performance is easily lowered by absorbing SOx, comprising:

a reductant fuel adding nozzle (7) for adding reductant fuel into said exhaust pipe (2);

a flow rate control valve (10) for controlling a feed rate of the reductant fuel to said reductant fuel adding nozzle (7);

an NOx catalyst inlet temperature sensor (14) disposed at an upstream side of said NOx catalyst (3); and

a regeneration control unit (17) for computing the quantity of SOx taken into said NOx catalyst (3) during a period of time in which the inlet temperature of said NOx catalyst (3) is not higher than a predetermined value from a signal from said NOx catalyst inlet temperature sensor (14) and an instruction of a zero feed rate is given to said flow rate control valve (10), from the quantity of the diesel fuel supplied to a diesel engine (1) during said period of time of zero feed rate, and outputting an instruction for supplying reductant fuel the quantity of which is larger than a predetermined quantity suitable for the operational condition of said diesel engine (1) to said flow rate control valve (10) when said inlet temperature exceeds a predetermined value and the reductant fuel is started to be added,

said apparatus regenerating said NOx catalyst (3), which has lower performance due to SOx, by adding the reductant fuel the quantity of which is larger than the quantity suitable for said operational condition.

2. The apparatus for regenerating an NOx catalyst for a diesel engine in accordance with Claim 1, further comprising:

either on of a selector switch (21) for selecting the kind of diesel fuel, or a component sensor (16) for detecting sulphur content in diesel fuel,

said regeneration control unit (17) computing the quantity of SOx discharged from said diesel engine (1) from a signal sent from either one of said selector switch (21) or said component sensor (16) and the feed rate of the diesel fuel to said diesel engine (1), and outputting to said flow rate control valve (10) an instruction to supply the reductant fuel the quantity of which is larger than a predetermined quantity suitable for the operational condition of said diesel engine (1) when said inlet temperature becomes a predetermined value or over and the reductant fuel is started to be added.

3. An apparatus for regenerating an NOx catalyst for a diesel engine, in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe (2) predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst (3) which is disposed in said exhaust pipe (2), and of which performance is easily lowered by absorbing SOx, comprising:

a reductant fuel adding nozzle (7) for adding reductant fuel into said exhaust pipe (2) at an upstream side of said NOx catalyst (3);

a flow rate control valve (10) for controlling a feed rate of the reductant fuel to said reductant fuel adding nozzle (7);

an NOx catalyst inlet temperature sensor (14) disposed at an upstream side of said NOx catalyst (3);

a hydrocarbon concentration sensor (12) disposed at a downstream side of said NOx catalyst (3); and

a regeneration control unit (17),

said regeneration control unit (17) outputting an instruction for adding reductant fuel the quantity of which is larger than a predetermined quantity suitable for the operational condition of said diesel engine (1) to said flow rate control valve (10) when the inlet temperature of said NOx catalyst (3) is higher than a predetermined value from a signal from said NOx catalyst inlet temperature sensor (14) and the hydrocarbon

concentration at the downstream side of said NOx catalyst (3) is be greater than a predetermined value from a signal from said hydrocarbon concentration sensor (12) to regenerate said NOx catalyst (3) which has a lower performance due to SOx.

4. A method for regenerating an NOx catalyst for a diesel engine, in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe (2) predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst (3) which is disposed in said exhaust pipe (2), and of which performance is easily lowered by absorbing SOx, comprising the steps of;

on regenerating said NOx catalyst (3) which has lower performance due to SOx,

computing the quantity of SOx which is taken into said NOx catalyst (3) during a period of time in which a diesel engine (1) is operated and addition of reductant fuel is stopped due to the inlet temperature of said NOx catalyst (3) being not higher than a predetermined value; and

adding a predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for the operational condition, to regenerate said NOx catalyst (3) deteriorated by SOx, when the operational condition of said diesel engine (1) is changed with said inlet temperature being higher than the predetermined value and the reductant fuel is added.

5. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for said operational condition, is the quantity of reductant fuel suitable for the operational condition to which fixed quantity of reductant fuel is added irrespective of the operational condition of the engine.

6. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for said operational condition, is the quantity of reductant fuel suitable for the operational condition, which is incremented by a fixed ratio.

7. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for said operational condition, is variable quantity which is obtained by computing from the NOx concentration in the exhaust gas, the exhaust gas flow rate, and the exhaust gas temperature which are determined by the operational condition, and the quantity of SOx taken into said NOx catalyst (3).

8. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein the quantity of SOx taken into said NOx catalyst (3) is computed from a feed rate of the diesel fuel to said diesel engine (1).

9. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein when the operational condition of said diesel engine (1) is changed with said inlet temperature being not higher than a predetermined value and addition of reductant fuel is stopped, before the regeneration of said NOx catalyst (3) is completed, the cumulative quantity of SOx in the NOx catalyst (3) at the time of stopping said addition is stored,

wherein the quantity of accumulated SOx in said NOx catalyst (3) during a period of time in which addition of the reductant fuel is stopped is obtained by successively adding the quantity of SOx, which is taken into said NOx catalyst (3) according to the operational condition of the diesel engine (1) during said period of time of stopping, to said stored cumulative quantity of SOx.

10. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein when said diesel engine (1) is stopped, before regeneration of said NOx catalyst (3) is completed, cumulative quantity of SOx in the NOx catalyst (3) at said time of stopping is stored,

wherein after said diesel engine (1) is stopped, said cumulative quantity of SOx is held, and

wherein next time when said diesel engine (1) is operated, the quantity of SOx, which is to be newly taken into said NOx catalyst (3), is successively added to said stored cumulative quantity of SOx.

11. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein the quantity of SOx which is taken into said NOx catalyst, (3) is obtained from the sulphur content in the diesel fuel supplied to said diesel engine (1).

12. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 4,

wherein when regeneration of said NOx catalyst is completed, the predetermined quantity of reductant fuel, which is larger than the quantity of reductant fuel suitable for said operational condition, is changed to the quantity suitable for the driving condition of the diesel engine (1) at the time of completion of said regeneration.

13. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 12,

wherein a point in time at which regeneration of said NOx catalyst (3) is determined to be completed is the time when a calculated quantity of residual SOx during regeneration becomes equal to or less than a predetermined value, after successively computing the quantity of SOx which is eliminated from said NOx catalyst (3) during regeneration and at the same time, computing the quantity of residual SOx during regeneration by subtracting the quantity of said eliminated SOx from the quantity of SOx remaining in said NOx catalyst (3).

14. The method for regenerating an NOx catalyst for a diesel engine in accordance with Claim 13,

wherein the quantity of SOx which is eliminated from the NOx catalyst (3) during said regeneration is obtained by computing from any one of the following: the NOx concentration in the exhaust gas, a flow rate of the exhaust gas, and the exhaust gas temperature which are determined by the operational condition of the diesel engine (1) during regeneration, the quantity of SOx which is taken into said NOx catalyst (3) and the quantity of the added reductant fuel.

15. A method for regenerating an NOx catalyst for a diesel engine, in an NOx catalyst device for a diesel engine, which reduces and controls NOx in exhaust gas by adding into an exhaust pipe (2) predetermined quantity of diesel fuel such as kerosene as reductant fuel being reductant hydrocarbon and by using an NOx catalyst (3) which is disposed in said exhaust pipe (2), and of which performance is easily lowered by absorbing SOx, comprising the step of:

on regenerating said NOx catalyst (3) which is deteriorated by SOx, adding the reductant fuel the quantity of which is larger than a predetermined quantity suitable for the operational condition of said diesel engine (1) when the inlet temperature of the upstream side of said NOx catalyst (3) is higher than a predetermined value and the hydrocarbon concentration of the downstream side of said NOx catalyst (3) is greater than a predetermined value.

REVISED VERSION

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/01418

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl^6 F01N3/36, F01N3/20, F01N3/08, B01D53/94, B01D53/86, B01D53/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl^6 F01N3/08-F01N3/36, B01D53/34-B01D53/96

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926 - 1997
Kokai Jitsuyo Shinan Koho 1971 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 60-33974, B2 (Mazda Motor Corp.), August 6, 1985 (06. 08. 85) (Family: none)	1 - 15
A	JP, 6-66129, A (Toyota Motor Corp.), March 8, 1994 (08. 03. 94) (Family: none)	1 - 15
A	JP, 7-217474, A (Toyota Motor Corp.), August 15, 1995 (15. 08. 95) (Family: none)	1 - 15
A	JP, 8-61052, A (Mitsubishi Motors Corp.), March 5, 1996 (05. 03. 96) & DE, 19522165, A1	1 - 15

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
July 23, 1997 (23. 07. 97)	August 5, 1997 (05. 08. 97)
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